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MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING  
PROGRAM QUARTERLY TECHNICAL REPORT

Contract Number DAAB07-76-C-8135

LIGHT EMITTING DIODES FOR FIBER OPTIC COMMUNICATIONS

Prepared By:

LASER DIODE LABORATORIES, INC.  
205 Forrest Street  
Metuchen, New Jersey 08840

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Fourth Quarterly Report  
For the Period 1 July 1977 to 30 September 1977

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Placed By:

U. S. Army Electronic Research and Development Command  
Fort Monmouth, N. J. 07703

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PROGRAM QUARTERLY TECHNICAL REPORT

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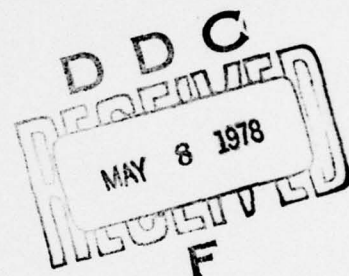
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LIGHT EMITTING DIODES FOR FIBER OPTIC COMMUNICATIONS

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Product Development Manager

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Fourth Quarterly Report  
for the Period 1 July 1977 to 30 September 1977

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The design and fabrication of high speed etched-well light emitting diodes for fiber optic communications is discussed with regard to materials synthesis via LPE, wafer fabrication, and device assembly in a manufacturing environment.		

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## SECTION I

### INTRODUCTION

The primary objective of this Manufacturing Methods and Technology Engineering Program is twofold. First, the manufacturing methods and techniques necessary for the volume production of the light emitting diode for use in fiber optic communications as outlined in Specification SCS-511 must be developed and implemented to insure the highest degree of device quality and reliability at a reasonable cost. Secondly, verification of device performance and quality for LED's produced in a volume manufacturing environment must be carried out by means of rigorous testing and evaluation in accordance with SCS-511 in order to demonstrate the technical adequacy of the manufacturing methods developed under this contract.

The major objectives for the fourth quarter of the program include zinc diffusion test runs to establish process conditions, construction of devices with production quality fiber -ferrule assemblies, beginning of life tests and assembly of second engineering samples for life testing and delivery.

## SECTION II

### MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING

#### 2.1 Wafer Processing for Etched Well Light Emitting Diode Chip Fabrication.

Activity in this area was concentrated on developing the zinc diffusion process. Runs processed so far have produced devices with low forward voltages, but in addition, the power output has been reduced. The principal cause of this reduction is the 'washing out' of the 'n' blocking layer during the zinc diffusion. When this occurs, the diode 'p' contact is transformed by the diffusion into a broad area contact. When biased at the normal drive current, the power output is reduced since the current density has been reduced, as is evidenced by the whole pellet lighting up at low intensity. Another condition which would produce the same affect would be one in which the zinc diffusion had not completely penetrated the 'n' blocking layer, but when the device is biased, the depletion layer would move through the 'n' layer and contact the 'p' cap layer thus producing a broad area effect. In order to overcome these effects, the 'n' blocking layer will be made thicker on the order of 2-3  $\mu\text{m}$ , and in addition, better control of the furnace temperature will be attained by precision control application. Table I lists forward voltage  $V_f$ , and power output  $P_o$ , on three trial runs.

TABLE I. ZINC DIFFUSION TEST RUNS

[illegible]

Figures 1 and 2 illustrate the re-alignment capability of the hinged mask set, with the index stop. Figure 2 depicts schematically the dot arrangement in Figure 1. In practice, the contact dot is exposed, developed, and the aperture etched. After the diffusion process steps, the wafer is re-inserted in the mask set, against the stop. Figure 1 is the photograph showing how the etched hole and the contact dot on the mask re-align. Since the alignment on the 'p' side is now correct, the mask set can be turned over and processed for the 'well' on the 'n' side, with assurance that the 'p' side contact and 'n' side 'well' will be concentric. Figure 3 is a photograph of the diode emitting from the contact centered in the 'well', taken through a microscope with a closed circuit television system. The microscope is focused on the bottom of the well. The drive current was reduced to a very low level, since at any moderate level, the light output was so intense that it would saturate the T.V. camera. Figure 4 and Figure 5 are cleaved pellet sections showing contact and etched well alignment.

Figure 6 is a photograph of a Motion Dynamics Model Mark II Dicing Saw used to dice the processed wafer. The machine features a high speed air-oil mist bearing, direct drive motor capable of speeds to 20,000 RPM, providing optimum conditions for smooth vibrationless cutting. The table has automatic variable travel and

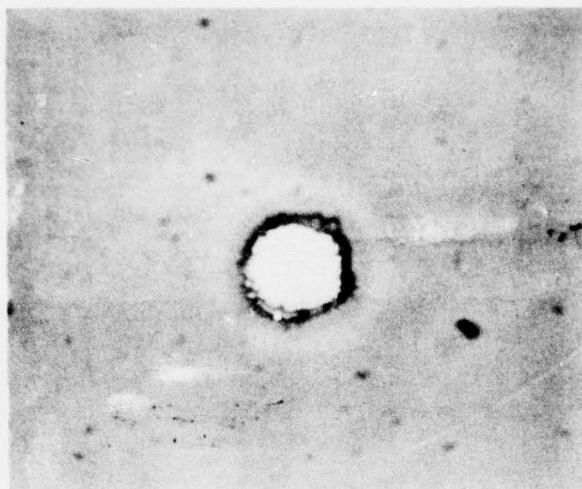


Figure 1. Dot Re-Alignment Photograph.

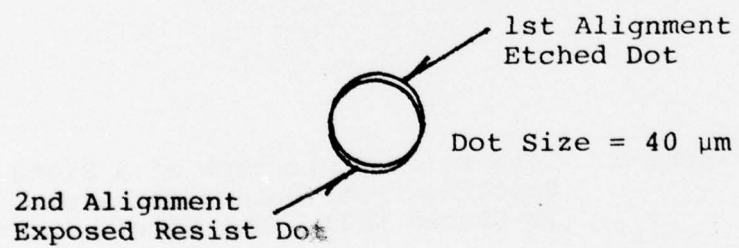


Figure 2. Details of Dot Re-Alignment.



Figure 3. Television Photograph of a Diode  
Emitting from Contact Dot Area  
in Etched Well. Dot Size = 40  $\mu\text{m}$ .

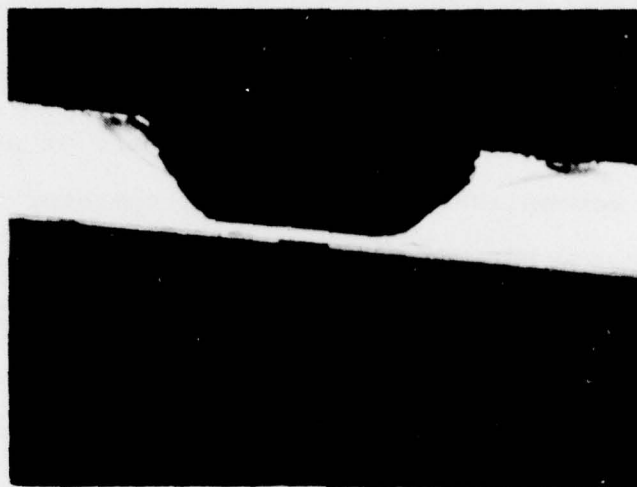


Figure 4. Cleaved Diode Section.

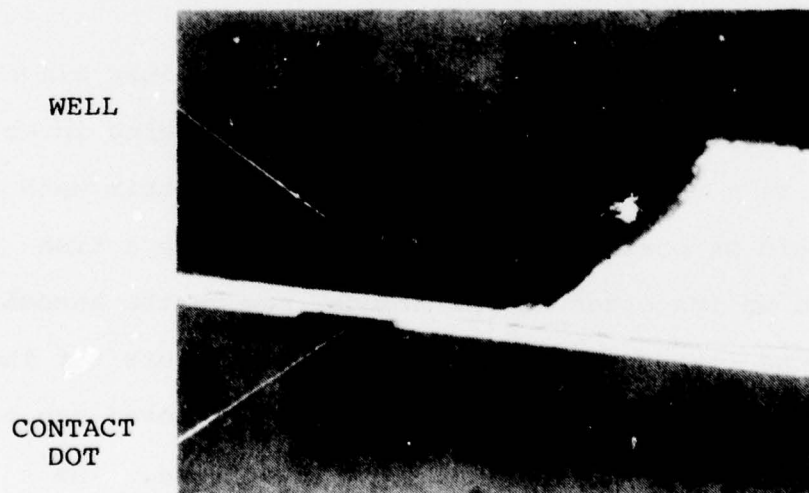


Figure 5. Detail of Cleaved Section.

speed control, while dice size cuts are indexed automatically. Figure 7 is a photograph of an LED illustrating the typical straight smooth-sided cuts obtained from the saw.

### 2.3 Diode Assembly Techniques.

Soldering of the diode to the header, at present, is being accomplished by individual operator technique. A proposed batch furnace soldering scheme is illustrated in Figure 8. The soldering jig contains the appropriate components to locate the parts and facilitate loading. Figure 9 is a photograph of the infra-red belt furnace which will be used to perform the actual soldering. The equipment contains a stainless steel, rack type belt and can be used in conjunction with inert gases for fluxless soldering. Belt speed, temperature and gas flow rate are all controllable for optimization of particular soldering conditions.

In order to increase the thru-put in the fiber alignment fixture, ultra-violet curing epoxies are being investigated as a temporary bonding agent. With this method it would be possible to secure the parts in a time period on the order of one minute, remove the assembly from the fixture, thereby freeing the fixture for the next device alignment. The assemblies removed can have the permanent epoxy applied at a later time. The epoxies tried to date require a very thin layer of material on the order of 10  $\mu\text{m}$  in order to cure within

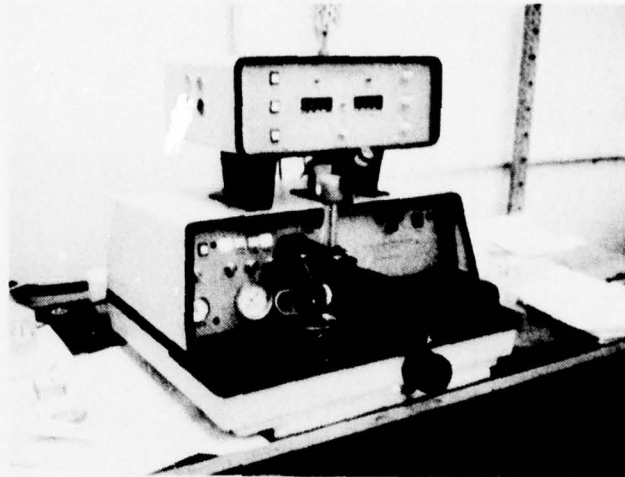


Figure 6. Motion Dynamics Model Mark II Dicing Saw.

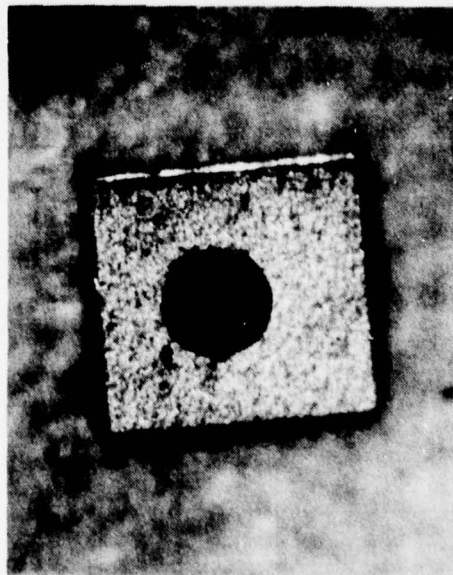


Figure 7. Typical Cut Obtained from Dicing Saw.

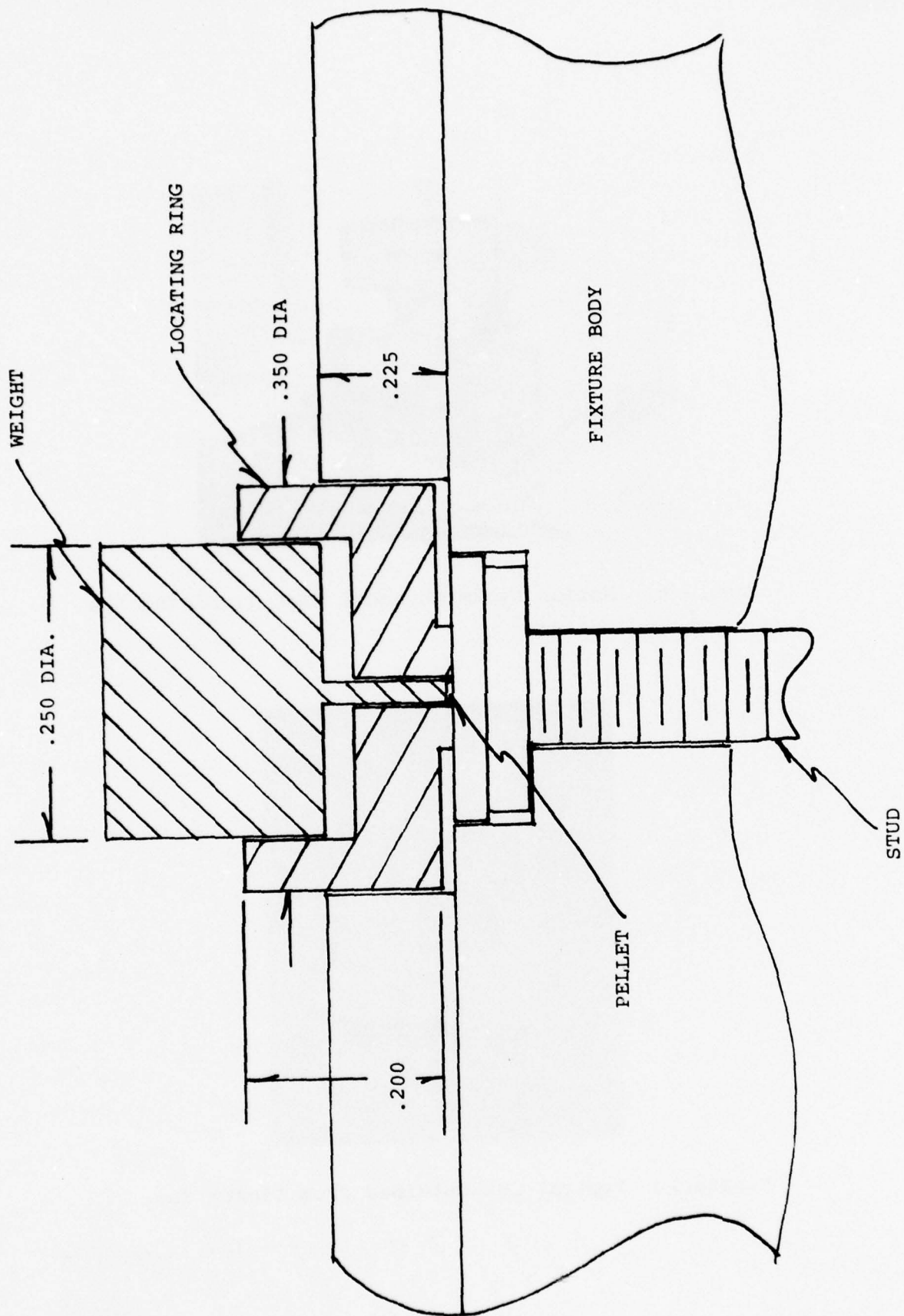


Figure 8. Batch Soldering Fixture.

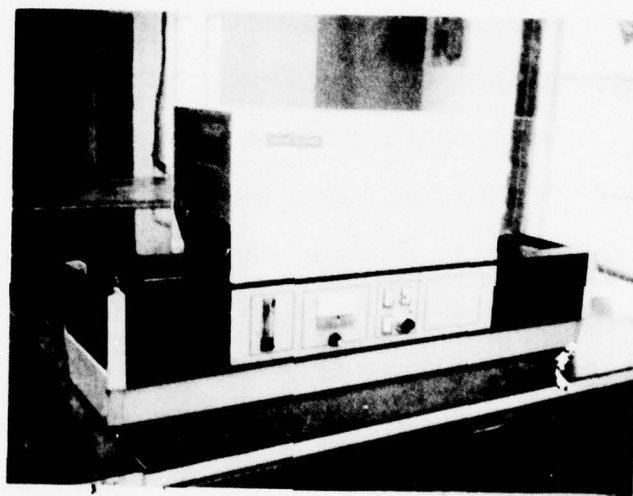


Figure 9. Infra-Red Belt Furnace.  
GCA Model 4101A

the one minute period.

## 2.4 Device Evaluation and Testing.

### 2.4.1 Device Evaluation.

Table II lists data on fiber coupled devices from Lot #BUR-B-42. This lot had been zinc diffused for eight (8) minutes at 650°C. The results, as indicated in the table, are in conformance with the requirements of SCS-511. Figures 10 through 14 are chart recordings of devices, taken with a spex spectrometer, illustrating the uniformity of peak wavelength,  $\lambda_p$  and spectral width at the 3 db intensity level. Figure 15 is a photograph of a linearity trace on a Hewlett Packard 8557A Spectrym Analyser, showing the second harmonic down greater than 35 db from the 1 MHZ fundamental. Figure 16 shows the fall off in power output for Lot #BUR-B-20 due to heating effects. Lot #BUR-B-42 is able to achieve much higher power levels before fall off occurs. Data for the curves was generated under D. C. conditions, and normalized for direct comparison.

## 2.5 Test Equipment

### 2.5.1 Life Testing

During this period two 2000 hour life tests were initiated. Lot #BUR-B-20 which began on 8/19/77 has completed 1000 hours by 9/30/77. This lot had good power output, but did not have low forward voltage. In addition, the units were assembled with the first fiber-ferrules which did not comply with the specification

outline drawing. Life test data is shown in Table III. Lot #BUR-B-42 was put on life test on 9/21/77 and will complete testing in December. This lot complies with SCS-511 in both characteristics and dimensional outline. The second engineering sample will be supplied from this life test group.

### SECTION III

#### SUMMARY AND CONCLUSION

During the fourth quarter fiber coupled devices with production quality fiber-ferrule parts were assembled. Zinc diffusion runs produced low forward voltage devices and life tests were begun on second engineering samples. Plans for the next quarter include completion of life tests, delivery of second engineering samples and characterization of devices.

TABLE II. Lot #BUR-B-42

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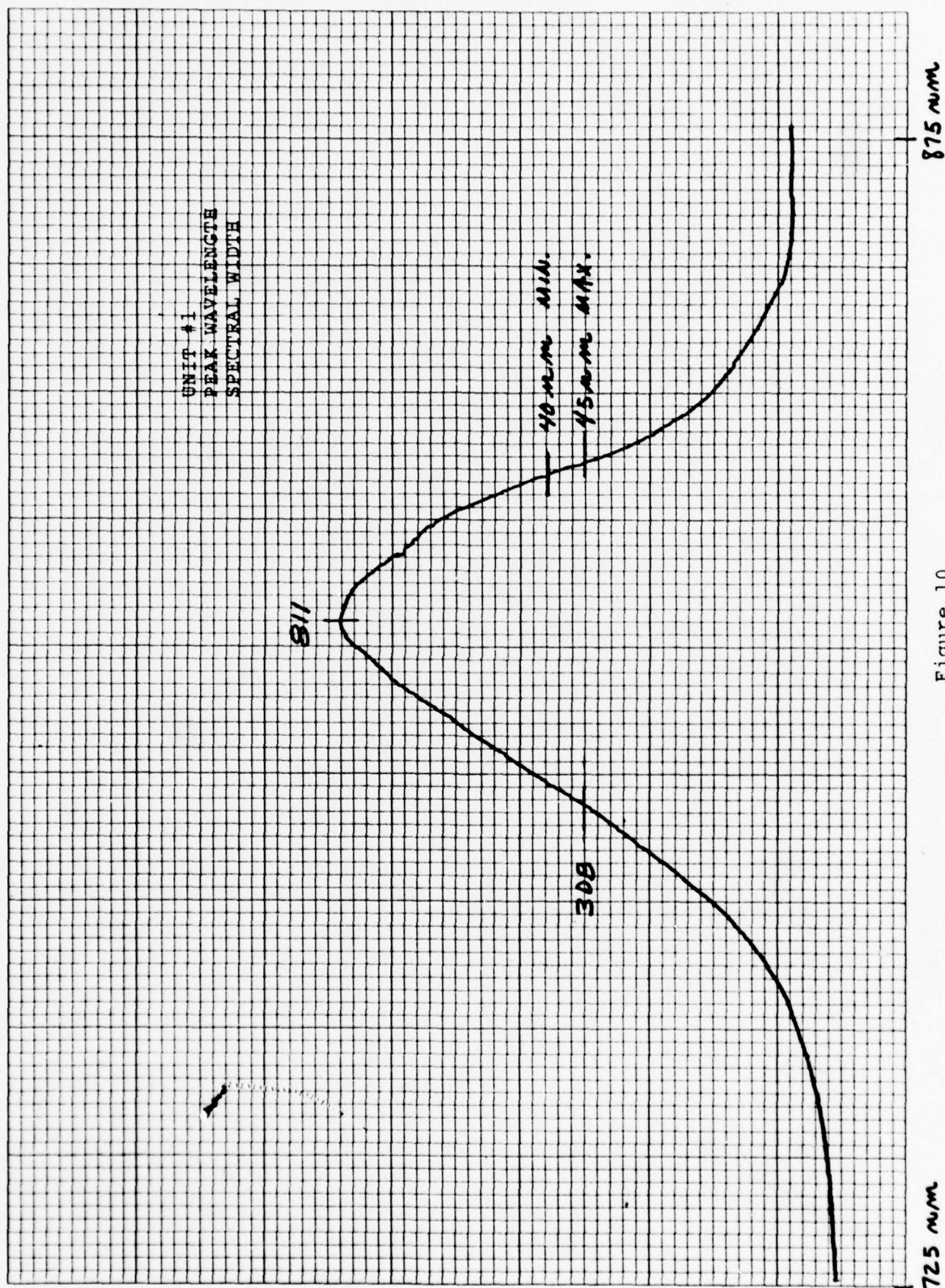


Figure 10

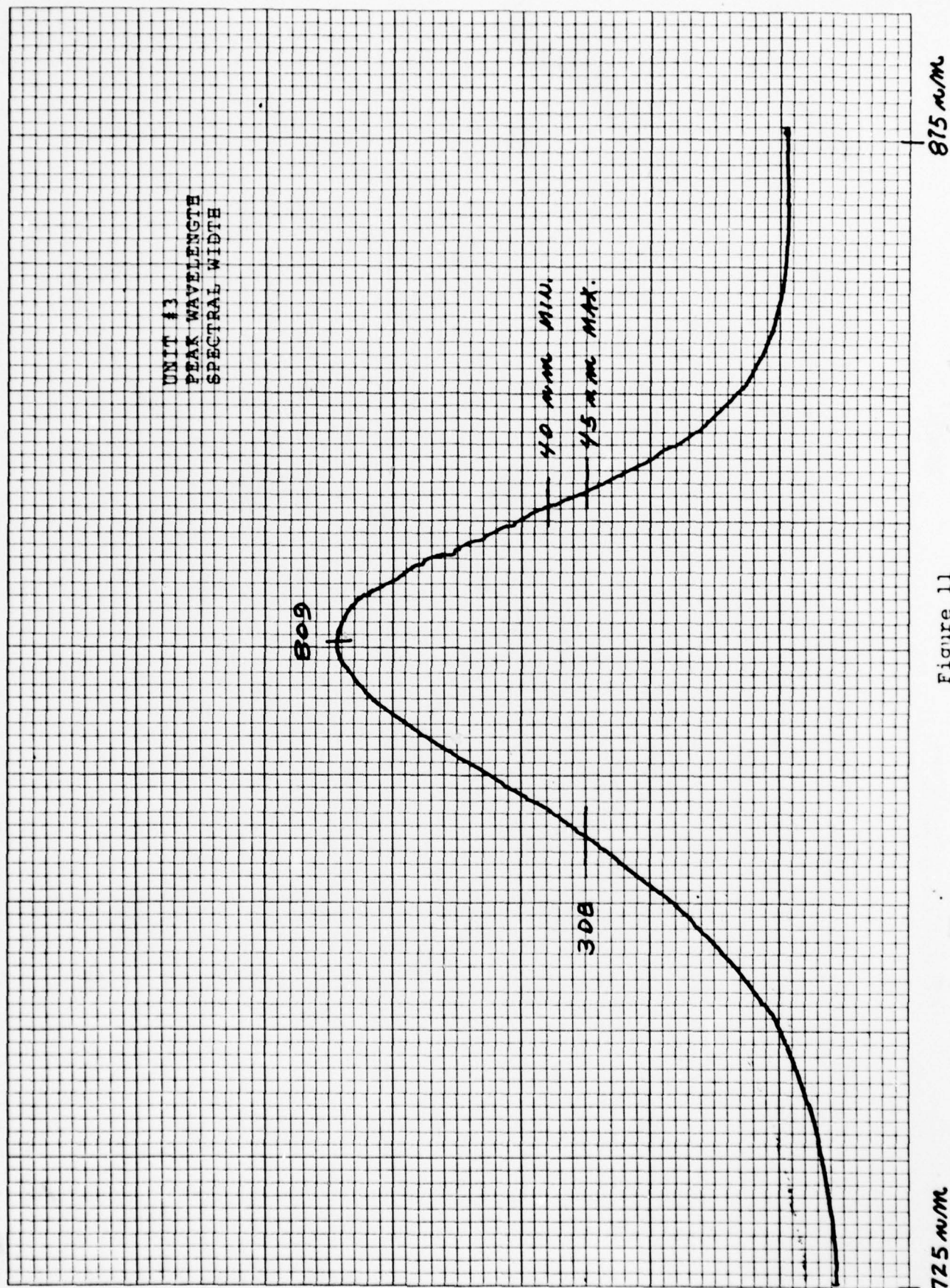


Figure 11

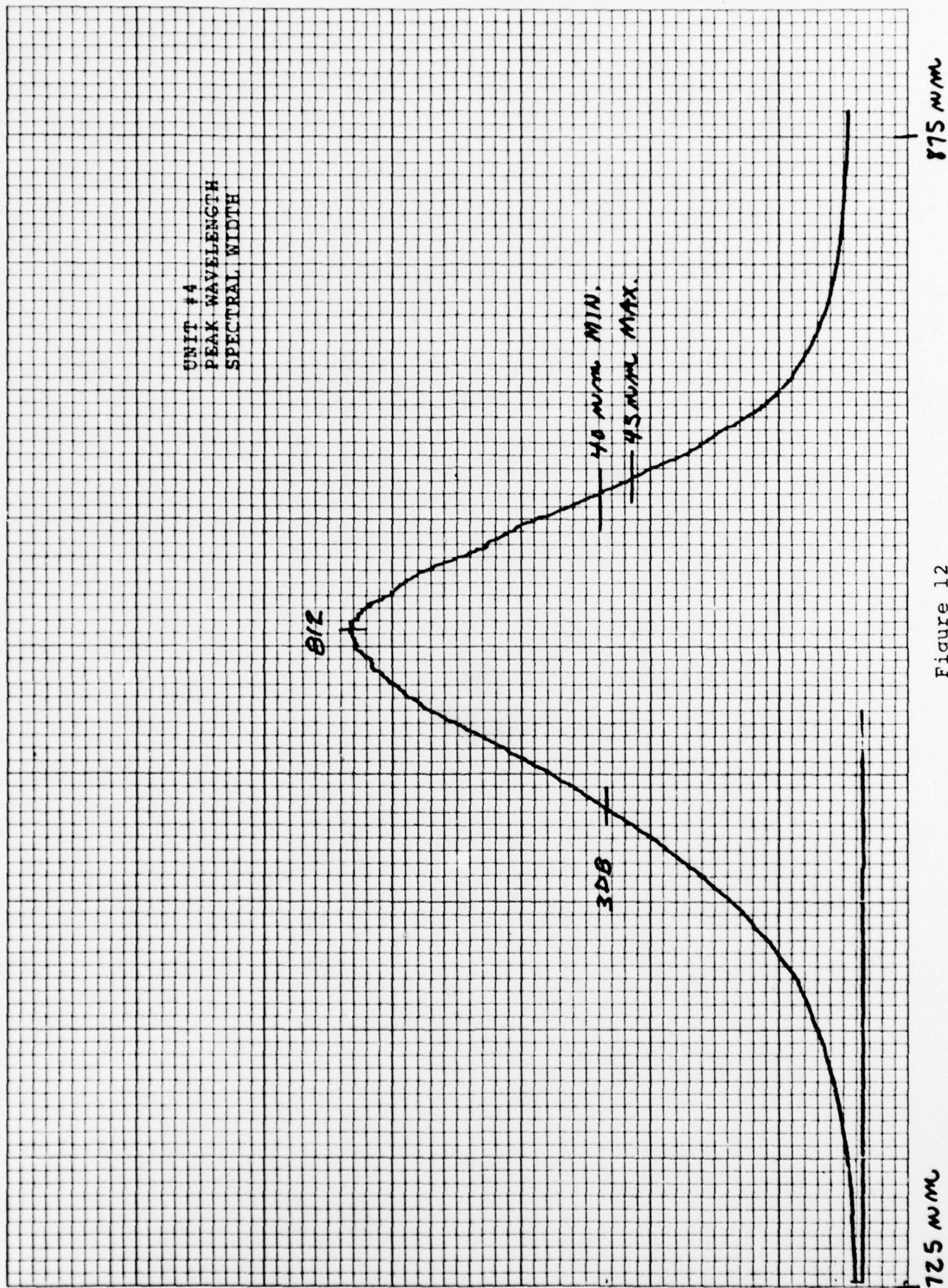


Figure 12

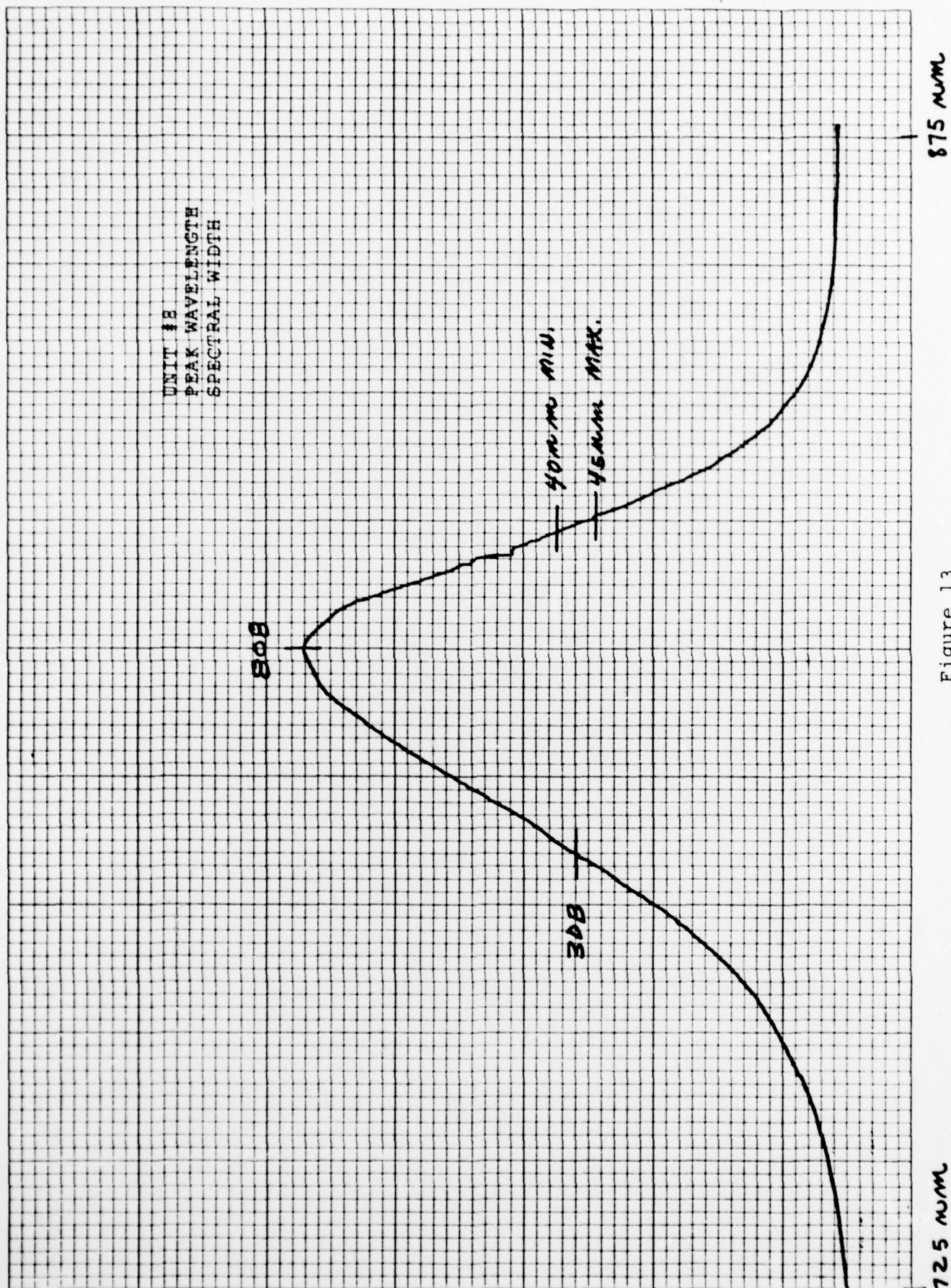


Figure 13

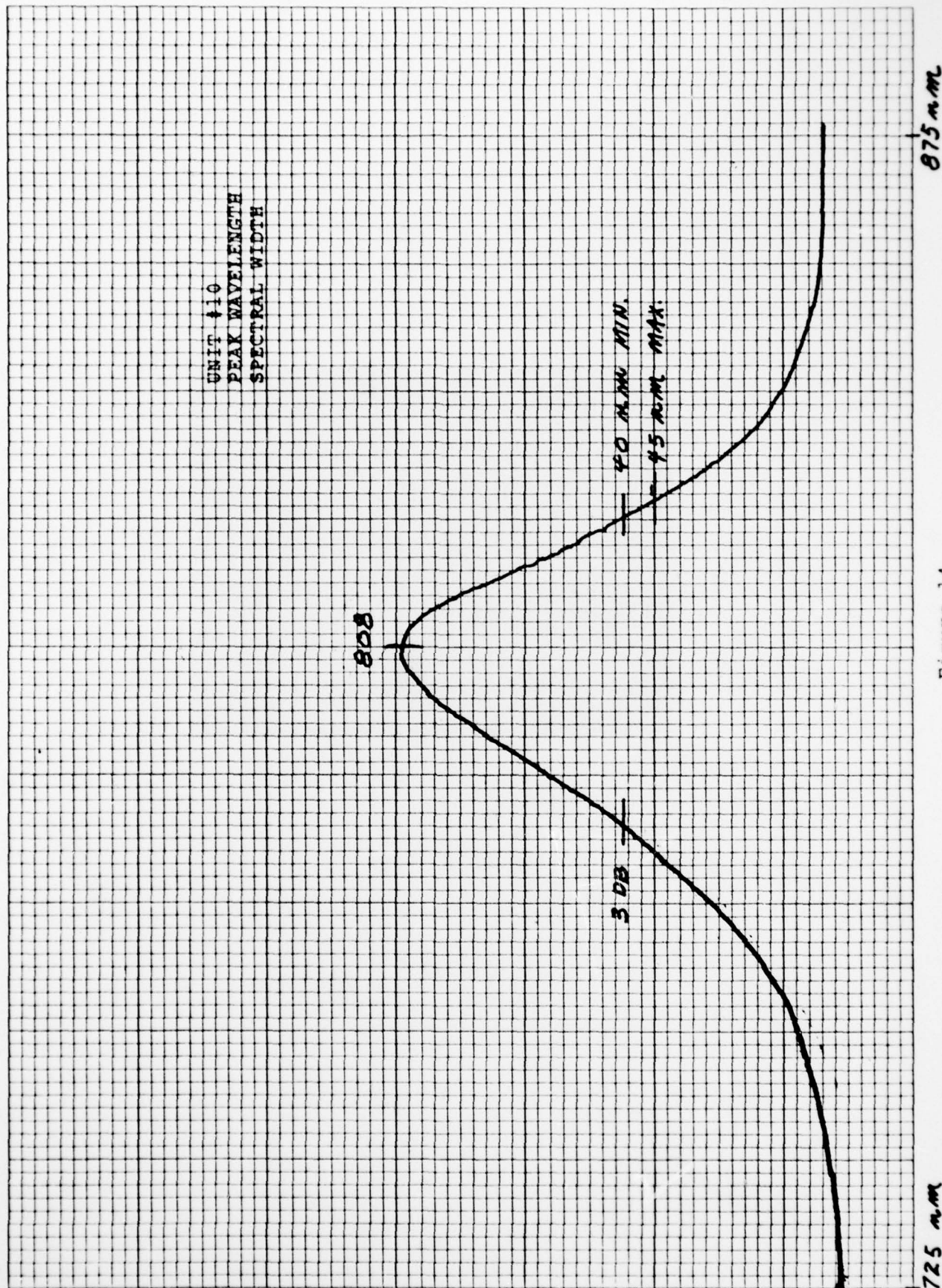


Figure 14

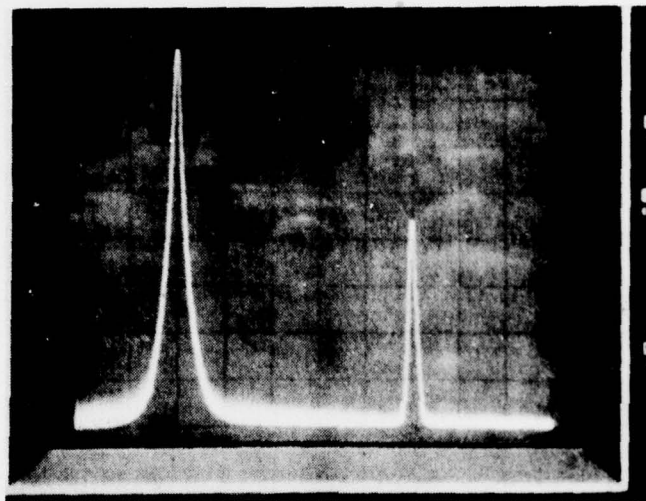
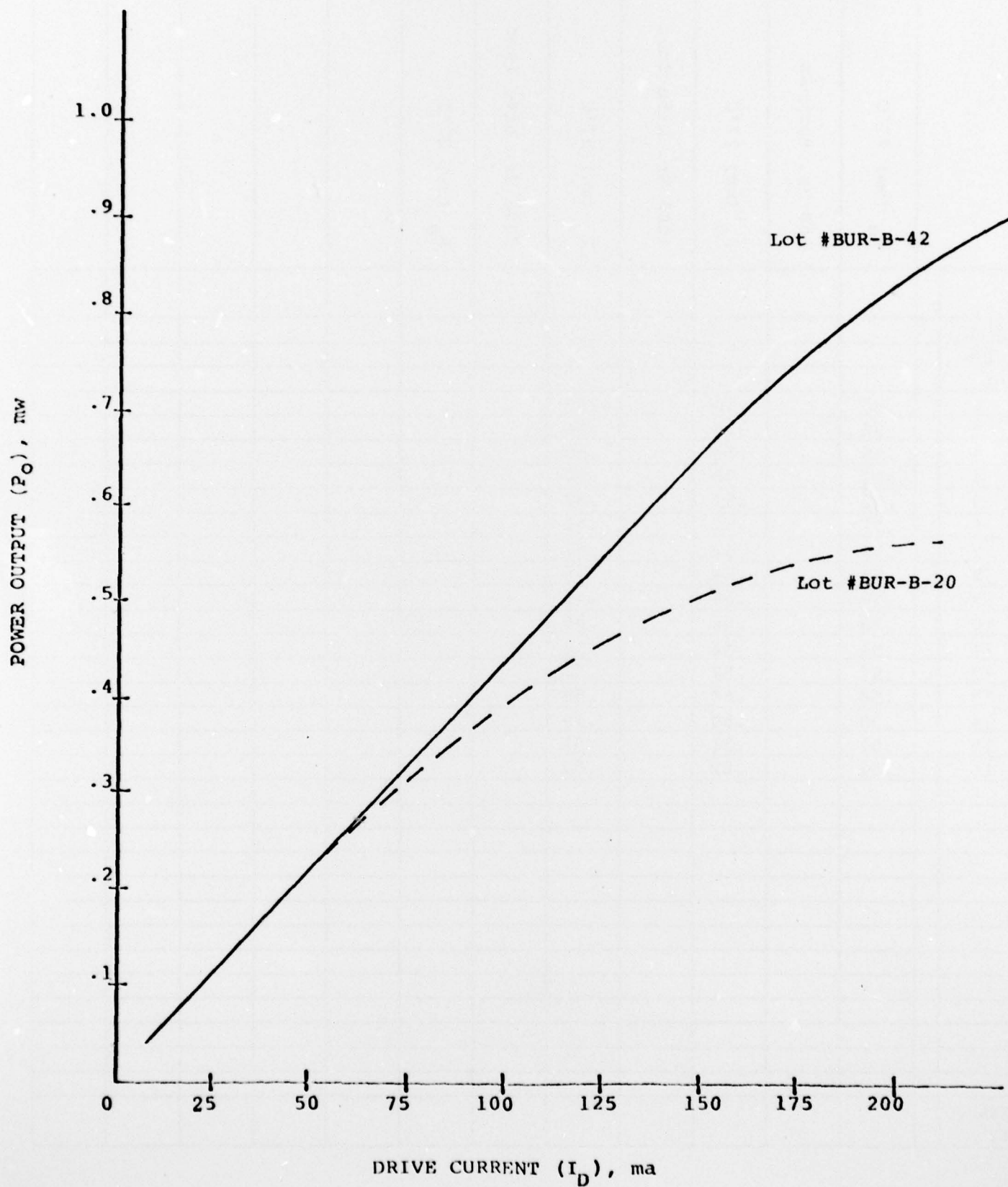


Figure 15. Linearity Trace.

Figure 16.  $P_O$  Vs.  $I_D$  Lot #BUR-B-42 and Lot #BUR-B-20



**TABLE III. LIFE TEST LOT #BUR-B-20**

[illegible]

APPENDIX A

Engineering Man-Hour Utilization for  
the Fourth Quarter of the Program.

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